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THE OHIO RIVER FLOOD OF MARCH, 1933[1]

WALLACE T. BUCKLEY

In March, 1933, the Ohio River Valley experienced the most severe flood since the disastrous overflow of 1913. From Point Pleasant, West Virginia, to Shawneetown, Illinois, the crest stage of this most recent flood was the highest since that of 1913, while at Cincinnati the river reached the fifth highest stage in its recorded history. Upstream from Point Pleasant the flood of March, 1933, was less severe than that of 1927. Attendant upon the overflow was the usual destruction of life and property as well as disruption of both land and water traffic along the Ohio Valley.

The cause and character of this flood becomes of special interest at this time because of the inauguration of the Muskingum Valley Project and proposals for the construction of an extensive system of flood-control reservoirs designed for the permanent prevention of floods in the Ohio River and its tributaries. Such a system would cost approximately $211,000,000 according to the estimate of Colonel Roger M. Powell, army engineer in charge of the Cincinnati office.[2] Under the proposed plan flood crests would be reduced some eight feet and river navigation would be facilitated by the maintenance of a standard water depth. The propensity of the Ohio River to flood is indicative of the need for control works. The complexity of the natural phenomena which lead to flood conditions in the Ohio Valley suggests the need for a comprehensive study of the causal factors.

[1]The writer wishes to acknowledge the assistance of Dr. Guy-Harold Smith, Department of Geography, Ohio State University, particularly in the preparation of the maps.

[2]The Enquirer, Cincinnati, May 3, 1934.

RECURRENCE OF FLOODS

Floods in the Ohio River Valley are not an unusual phenomena. River records for Cincinnati, located about midway between the mouth of the river and Pittsburgh, show that in the seventy-two-year period ending in 1931, flood stage has been reached at this point no less than thirty-five times. On this basis a flood may be expected about every other year. However, the river departs from the average in regard to the timing of its floods. On but eleven occasions has the flood occurred on alternate years. On five occasions floods have been separated by two-year intervals, once by a three-year interval and on two occasions five year periods passed without the river leaving its banks. Twice floods have occurred on three successive years and a four year period, ending in 1918, was featured by a flood each year.

The seasonal occurrence of high water shows less irregularity in the seventy-two year period under consideration. February leads with twelve floods, March is second with nine, January and April have six and five respectively, while December and August are each credited with one.

The Ohio River shows a great variability in the severity of its floods, not only as measured by comparisons of crest levels at a particular station, but also as measured by comparison of crest levels taken at several points along the stream. Cincinnati, taken as an example of a particular station, has recorded a total of thirty-five floods of which only two have approached a crest level of twenty feet above flood stage, and only six have reached a level of ten feet above the river's banks. In contrast, eighteen of the thirty-five floods recorded at this station have had a crest of less than four feet above flood stage. In regard to comparison of flood severity at selected points along the river, the March, 1933 flood produced the highest crest since 1913 for stations from Point Pleasant, West Virginia, to Shawneetown, Illinois. However, five floods at Pittsburgh since 1913 have exceeded the crest level of the 1933 flood at that point, while the flood of 1922 produced a higher crest at Paducah, Kentucky.

The character of the floods in the Ohio Valley as revealed by the existing records permit few valid generalizations, except perhaps, that floods do occur frequently. It is important, however, that the cause and character of these floods be determined and this information be used as a background for effective flood prevention and control works.

THE CAUSE AND CHARACTER OF THE MARCH, 1933, FLOOD

In the report of the United States Geological Survey on the Ohio Flood of 1913, the authors remarked that it was fortunate that the precipitation which caused the flood had occurred first on the lower tributaries of the river, giving them a chance to run out before the floods of the upper tributaries had entered the main stream. They suggested that the reverse might occur at some time with one flood reinforcing the other with disastrous results.[3] This forecast came true in the 1933 flood with the important exception that this most recent flood did relatively little damage.

Floods in the past have been due to a variety of causes, namely, excessive rainfall, rapid melting of accumulated snow, failure of reservoirs, forming and breaking of ice jams and breaking of levees.[4] The flood of 1913 resulted from excessive rainfall on saturated ground. The flood of 1933 resulted from exceedingly heavy precipitation, but its severity was intensified by the peculiar distribution of the rainfall in the middle and upper drainage basin of the Ohio River. There were two distinct rainstorms in the basin to which the flood may be attributed. The first storm occurred on March thirteenth, fourteenth and fifteenth, and the second on March eighteenth, nineteenth and twentieth, with a rainless period of about forty-eight hours intervening. During each storm rain was general over the entire drainage basin, but the maximum fall in the first storm occurred in the upper valley while that of the second storm was centered in the middle portion of the basin.

THE FIRST STORM

On March twelfth, the day prior to the first storm, the Ohio Valley experienced fair weather and rising temperatures. The river was at about average stage from Pittsburgh to Cairo, and the ground was not overly moist since precipitation for the preceding months of January and February was below normal for the greater part of the drainage basin. An extensive

[3]A. H. Horton and H. J. Jackson, "The Ohio River Flood of March-April, 1913." U. S. G. S., Water Supply Paper No. 334, 1913, p. 46.
[4]Ibid., p. 13.

low pressure area was moving eastward over the Northern Rocky Mountains. On Monday morning, March thirteenth, the first day of the first storm, this Low was centered over Iowa. Violent thunder storms occurred throughout the Ohio Valley and rain was general east of Louisville. The turbulent

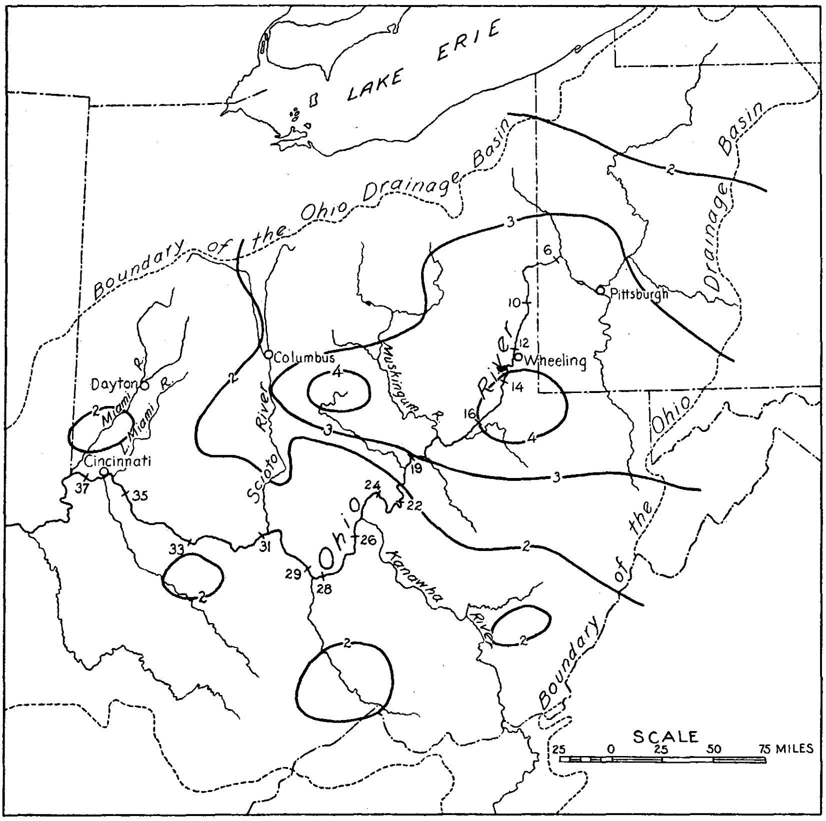

FIG. 1. Distribution of precipitation for March 13, 14, and 15, 1933. Note the heavy rainfall in the upper Ohio Valley with over four inches in the Wheeling district and on the headwaters of the Hocking River. (Numerals along the Ohio River indicate the location of dams.)

character of the atmosphere is indicated by the observations at Lunken Airport, Cincinnati. Calm wind was recorded at the surface while an eighty-three miles an hour gale was blowing at an elevation of 2,500 feet above the surface.[5]

[5]Daily Weather Map. Cincinnati Office of the Weather Bureau. March 13, 1933.

By the fourteenth, the second day of the storm, the Low had advanced to central Michigan and had developed a secondary which was centered over Arkansas. This trough of low pressure, crossing the Ohio Valley, brought the second day of general rain to the district. On the morning of the fifteenth the Low and its secondary had merged and were centered over eastern Pennsylvania. During the day the rain ceased and the skies cleared in the Ohio Valley.

The rainfall which accompanied the first storm reached its maximum amount in the Wheeling district and on the headwaters of the Hocking River, each district receiving about four inches of rain as a total for the three days. The average rainfall for the entire month of March is three and one-tenth inches at Wheeling and two and nine-tenths inches at Athens on the Hocking River. The distribution of rainfall in the Ohio Drainage Basin for the three-day storm period is indicated on Figure 1. The three-inch isohyet includes the greater part of the basin east of the Muskingum River, while the two-inch isohyet reaches as far west as Wilmington, Ohio. In addition, isolated areas receiving two or more inches of rainfall are found in the middle Ohio Valley.

The most notable feature in the distribution of the rainfall of the first storm is its maximum in the upper or eastern portion of the Ohio Drainage Basin.

THE SECOND STORM

The two-day interval between the rain storms was featured by the passage of two anti-cyclones in succession over the Ohio Valley. Moving in from the West Coast, however, was an extensive low pressure area that brought this period of fair weather to an end.

On the morning of the eighteenth this Low was centered over southern Kansas and covered the greater part of the United States with the exception of the Pacific Coast. An equally extensive high pressure area spread over Canada with its center north of Lake Huron. Under such conditions the predicted track of the cyclone led south of the Ohio Valley, probably through Tennessee. On the expectation that the northern section of the Low would pass over the valley, the Cincinnati Office of the Weather Bureau predicted unsettled weather for the eighteenth and clearing weather for the nineteenth.[6] The Low, however, turned at right angles to its estimated course and moved north at a slow rate. The movement of the storm center from the eighteenth to the twentieth is estimated to be at a speed of about thirteen miles per hour or less than one-half the normal winter rate. From

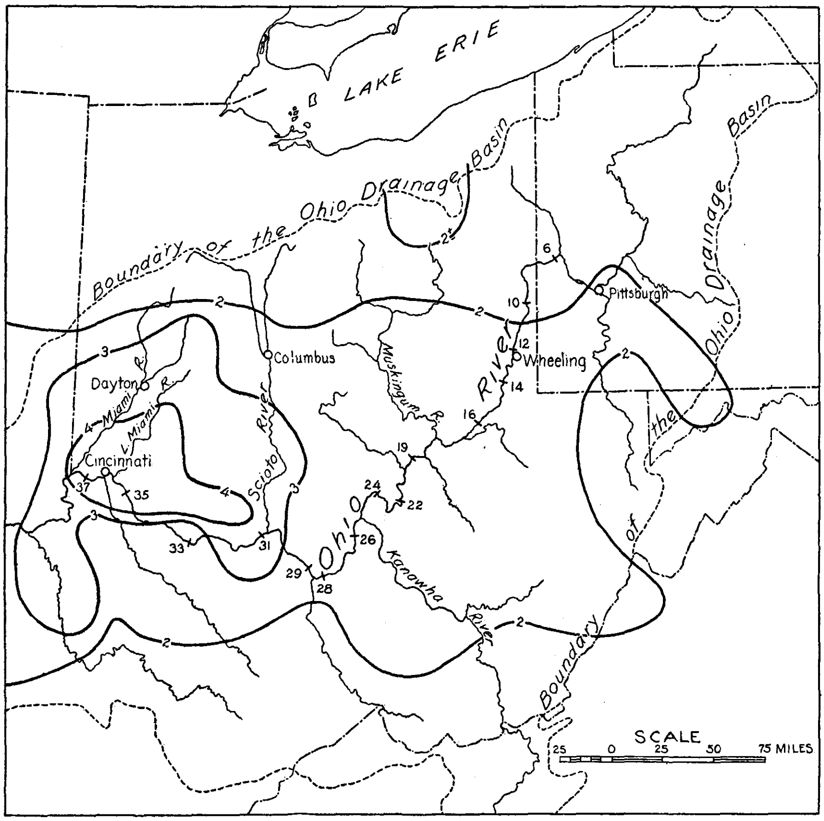

FIG. 2. Distribution of precipitation for March 18, 19, and 20, 1933. The rainfall of the second storm reached its maximum in the Cincinnati district. Compare with Fig. 1.

its position over Kansas on the eighteenth the Low moved over Cincinnati on the twentieth and on the twenty-first was centered over lower Michigan. From here it moved northeastward down the St. Lawrence Valley.

[6]Daily Weather Map. Cincinnati Office of the Weather Bureau, March 18, 1933.

The rainfall which accompanied the passage of this cyclone over the Ohio Valley began falling on the afternoon of the eighteenth and was general and more or less continuous over the entire valley until the morning of the twentieth. In contrast to the first storm, the maximum fall occurred in the middle rather than the upper valley, and the total amount for the three-day storm period was greater. (See Fig. 2.)

Five and two-tenths inches of rain fell at Cincinnati, the heaviest recorded in either storm. "The greatest rainfall [at Cincinnati] in thirty-six hours was nearly five inches, and the rainfall was at the rate of one inch per hour for a considerable time."[7] Two inches or more of rain occurred in nearly all of the Ohio Basin in the second three-day storm period.

The approach of a third storm in the series which brought flood conditions to the Ohio Valley in March, 1933, gave rise to the possibility of an even more severe flood than was experienced. This low pressure area was centered over northern Texas on the twenty-second of March and the presence of a high pressure area over Florida enhanced the probability of the movement of the storm area over the Ohio Valley. The prospect of a third rainstorm over the then flood-stricken district was regarded with apprehension. Special data on the progress of this low were collected by the Cincinnati Office of the Weather Bureau and two special Weather Maps were constructed in one day.[8] Fortunately, the storm moved eastward over Tennessee and the precipitation in the Ohio River Basin was negligible.

The total precipitation which fell in the upper and middle drainage basin of the Ohio River from March thirteenth to March twentieth amounted everywhere to more than three inches. Thus, in the area at large, the rainfall of an eight-day period about equaled the normal precipitation for the entire month of March. The maximum fall for the entire basin was in the Cincinnati district where seven and eighty-five hundredths inches were recorded. In the upper valley, Wheeling had a total of six and fifty-four hundredths inches, while near the mouth of the Muskingum River six and forty-two hundredths inches of rain fell in the two storm periods.

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[7]R. T. Zoch, "Monthly Weather Review." U. S. W. B., June, 1933, p. 16.
[8]The Enquirer, Cincinnati, March 23, 1933.

The fact that in this particular flood period the heaviest rainfall occurred within a few miles of the Ohio River itself acquires an added significance in regard to the proposals to control the flood waters of the Ohio by means of storage dams

	MARCH 13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
Pittsburgh	-F	-R	+R	+F	-F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 6	-R	-R	+R	+F	+F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 10	-R	-R	+R	+R	+F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 12	-F	-R	-R	+R	+F	-F	-R	-R	-R	-F	-F	-F	-F	-F	-F	-F		
Dam 14	-F	-R	-R	+R	+F	-F	-F	-F	-R	-S	-F	-F	-F	-F	-F	-F		
Dam 16	-F	-R	-R	+R	+F	+F	+F	-F	-R	-S	-F	-F	-F	-F	-F	-F		
Dam 19	-F	-R	-R	+R	+S	+F	+F	+F	+F	+R	+F	-F	-F	-F	-F	-F		
Dam 22	-F	-R	-R	-R	+R	+F	+F	+F	+S	+S	+F	-F	-F	-F	-F	-F		
Dam 24	-F	-R	-R	+R	+R	+R	+S	+S	+S	+S	+F	+F	-F	-F	-F	-F		
Dam 26	-F	-R	-R	-R	+R	+R	+R	+R	+S	+S	+F	+F	+F	-F	-F	-F		
Dam 28	-F	-R	-R	-R	-R	-R	+R	+R	+S	+S	+S	+F	-F	-F	-F	-F		
Dam 29	-F	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	-F	-F	-F		
Dam 31	-F	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	-F	-F		
Dam 33	-S	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 35	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 37	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 38	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	+F	-F	
Dam 39	-R	-R	-R	-R	-R	-R	+R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F	
Dam 41	-R	-R	-F	-R	-R	-R	-R	+R	+R	+R	+R	+F	+F	+F	+F	+F	+F	-F

- Below Flood Stage F River Falling
+ Above Flood Stage R River Rising
S River Stationary

FIG. 3. Progress and duration of the flood. The broken lines inclose the periods of rising water, while the solid lines indicate the flood interval at selected stations along the Ohio River. Note the difference in the incidence and duration of the flood in the upper and middle valley.

on the headwaters of the major tributaries. The precipitation above the storage dams of the Miami Conservancy District averaged about three inches, while below the control works the rainfall for the flood period averaged about five inches. As a result of the peculiar distribution of rainfall in the Miami

Valley, minor overflows occurred in the vicinity of Middletown and Hamilton and the Conservancy Dams were of little, if any, benefit in retarding the progress of the flood waters of the Ohio River. On the contrary, it is possible that the channel improvement on the Miami River south of Dayton speeded the runout of its waters, thus intensifying the flood of the Ohio River.

PROGRESS AND DURATION OF THE FLOOD

On the morning of March thirteenth the Ohio River was at about average stage from Pittsburgh to Cairo. The general rains which accompanied the first storm began on the morning of the thirteenth and continued until the afternoon of the fifteenth, with the heaviest precipitation occurring in the upper portion of the valley. In response to this storm the river rose throughout its upper and middle course and on the morning of the sixteenth was above flood stage from Pittsburgh to Dam Twenty-four (Pomeroy, Ohio). At Louisville, Kentucky, however, the river was at approximately the same stage as on the preceding day. (See Fig. 3.)

During the interval of rainless weather which prevailed from the afternoon of March fifteenth to the afternoon of the eighteenth, the crest of the flood waters passed downstream bringing flood conditions to the valley from Dam Fourteen (St. Marys, West Virginia) to Dam Twenty-nine (Ashland, Kentucky). Above Dam Fourteen the river had subsided to within its banks while below Dam Twenty-nine, although the river was approaching flood stage, the prospect was for a flood of minor character. It was estimated by the Cincinnati Office of the Weather Bureau on the morning of the eighteenth that the approaching crest would bring the river to a level of about fifty-two feet or approximately flood stage at that point.[9] On the afternoon of the eighteenth the rains of the second storm began, and while general over the entire valley, reached their maximum in the Cincinnati District. The rapid inflow of water from this second storm reinforced the waters of the first and changed what promised to be a flood of minor character into one of major proportions.

Since the rainfall of the second storm was relatively light in the upper portion of the valley, it failed to bring the river

[9]Daily Weather Map. Cincinnati Office of the Weather Bureau, March 18, 1933.

to flood stage again upstream from Dam Fourteen. At Pittsburgh the river had fallen to a level of about seven feet below flood stage on the morning of the nineteenth. Twenty-four hours later the run-off of the upper tributaries had filled the channel to within two feet of flood stage, but the maximum flow of the stream passed without a second period of overflow.

Down stream from Dam Fourteen, where the effect of the first storm was still expressed either by flood conditions or rising water, the run-off of the second storm increased the height of the then existing flood and extended the flood zone to the vicinity of Louisville, Kentucky.

The influence of the dual storms is seen in the difference in the duration of the flood period in the upper and middle Ohio Valley. At Pittsburgh the river was in flood for two days, while at Dam Sixteen the overflow persisted for four days. Below this point where the waters of the first storm were reinforced by those of the second the flood interval was noticeably longer. Dam Nineteen experienced an eight-day flood or twice that of Dam Sixteen. Here the crest of the flood was reached on the sixteenth, early in the flood period, but subsidence of the river was so retarded by the second storm that flood conditions prevailed for six days after the crest had passed.

In the middle portion of the Ohio Valley where the flood waters of the two storms were merged, the flood period was from eight to ten days with the crest occurring about midway in the interval. At Cincinnati, the river passed flood stage between nine and ten o'clock on the evening of the eighteenth, soon after the second storm began, and rose at an average of about one-tenth foot per hour until the crest was reached at 5 P. M. on the twenty-first. This crest stage was held without noticeable change for fifteen hours. The run-out of the flood waters at this point required about five and one-half days after the river had started to subside. The tendency for the flood period to become progressively longer down stream is indicated further by the fact that the river remained above flood stage for ten days in the Louisville district as compared with a flood interval of fourteen days at Paducah, Kentucky. For a period of thirty days, beginning March fifteenth, the Ohio River at some point in its course from Pittsburgh to Cairo, was above flood stage.

Any plan designed for complete control of the waters of the Ohio must have multiple objectives. The control works must be comprehensive enough to retard effectively excessive stream flow when floods threaten. This will permit the development of riverine properly with a minimum of danger of loss from floods, and render navigation dependable in all seasons. Furthermore, the system of control works must be so planned that in periods of deficiency a river stage of depth sufficient for navigation may be maintained by increasing the discharge from the storage reservoirs. Such a plan implies an efficient and centralized control. It also implies, according to preliminary estimates, an expenditure of over $200,000,000. If the monetary cost of this vast project be balanced against the benefits which would accrue to the nation from a controlled Ohio River and the undertaking be found economically desirable, there still remains the development of an effective system of control works. The distribution and timing of the precipitation in the Ohio Drainage Basin which resulted in the flood of March, 1933, exemplifys but one of the many problems inherent in the control of the major stream through regulation of the flow of its larger tributaries.

Morphology of the Algae

Fritsch has added another distinguished volume to the subject of algology in giving us for the first time a comprehensive account of the morphology of the algae in the English language. The aim of the book is to present "a broad treatment of the subject-matter, such as will give a general review of the characteristics and interrelationships of the diverse group of Protista . . ." Phases of ecology, physiology, and taxonomy are dealt with only in so far as they are of general morphological interest. Some attempt is made to discuss the results of the vast number of cytological investigations. An introductory division of 59 pages discusses algae and flagellates, special structural features, and the general course of reproduction in algae. The classes of algae are then treated in more detail in order: Chlorophyceae, Xanthophyceae (Heterophyceae), Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonadineae, Euglenineae, and the Colorless Flagellata. Volume II will presumably treat the Myxophyceae, the Rhodophyceae, and the Phaeophyceae.

The book is of the greatest value to morphologists and students of the algae in its organization of data amassed during the last three or four decades and in the very complete and carefully selected references to literature.

American algologists will be inclined to approve Fritsch's return to "Chlorophyceae" (instead of "Isokontae") and to his inclusion of Dinophyceae and Euglenineae in a discussion of algal relationships. One could wish for more of the clarity and artistry attained by the late Professor G. S. West in the numerous figures and plates in the present volume.—L. H. TIFFANY.

The Structure and Reproduction of the Algae, Vol. I, by F. E. Fritsch. xiii+791 pp. Cambridge, at the University Press; New York, the Macmillan Co., 1935. $8.00.